Wylfa Newydd

Horizon Nuclear Power

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Sewage bacteria modelling

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Project Manager:	Rob Bromley
Author:	Coastal Science

Jacobs U.K. Limited

Kenneth Dibben House
Enterprise Road, Southampton Science Park
Chilworth, Southampton SO16 7NS
United Kingdom
T +44 (0)23 8011 1250
F +44 (0)23 8011 1251
www.jacobs.com

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1. Introduction

During the construction phase of the Wylfa Newydd project, it is proposed that two sewage discharges would be operational, one from the northern end of the proposed Western Breakwater, and one from the “Campus” location, nearshore to the west of Wylfa Head.

It is proposed that the Campus effluent would be merged with, and share an outfall with, a Dwr Cymru – Welsh Water (DCWW) discharge.

This report provides the output of additional detailed numerical modelling undertaken in order to assess the cumulative impact of the two proposed construction discharges and the DCWW discharge on water quality at the designated Cemaes Bathing Water site, to the east of Wylfa Head. The additional modelling has been completed in response to NRW’s perception that high bacteria values were being predicted by the original modelling at Cemaes Bathing Water.

For the purposes of the updated assessment, the Horizon Nuclear Power (HNP) 3D Wylfa hydrodynamic model has again been employed, but utilising advection dispersion modelling rather than particle tracking. This model has been developed during the period 2010 to 2016, and is underpinned by a very extensive bespoke marine and aerial survey dataset for the purposes of model build, calibration and validation. The model was subject to a detailed 2-stage peer review in 2016, and was subsequently applied to the assessment of Cooling Water dispersion, Total Residual Oxidant dispersion and a range of dredging studies.

2. Model Background

The model utilised for this study is the high resolution HNP Wylfa coastal model of the North Anglesey coast and surrounding waters, the model being purpose built between 2010 and 2016 for use in the assessment of dispersion of effluents from the proposed new build power station at Wylfa.

The hydrodynamic and dispersion model, operating in the Delft3D software environment, represents part of the Irish Sea with a particular focus on the waters around Wylfa Head and Cemaes Bay, where model resolution was set to 23m. Further afield, the model resolution decreases to 70m and then to 350m. The model is shown in Figure 1 and Figure 2.

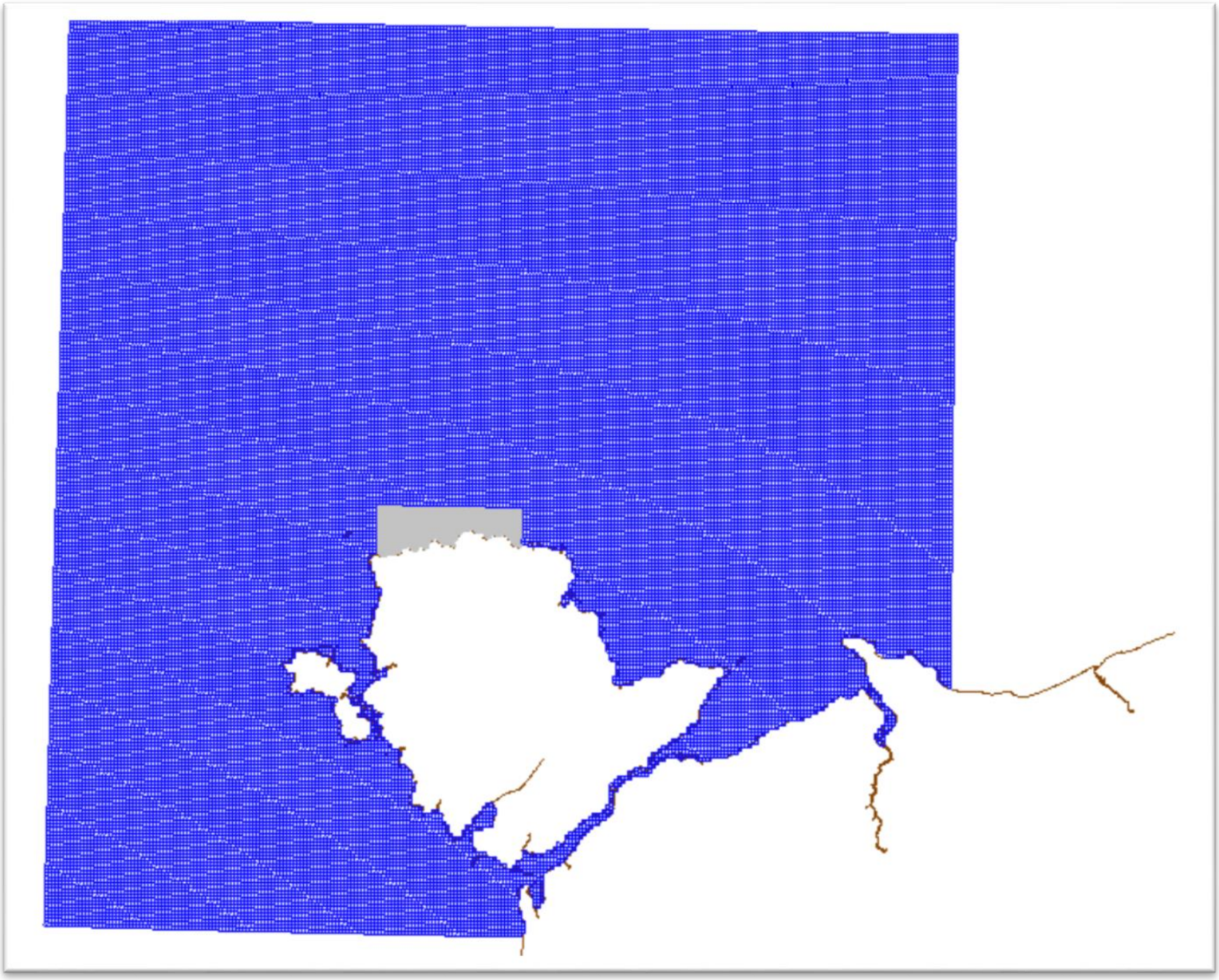


Figure 1 - HNP Wylfa Coastal Model, full extent of model grids (shaded grey area- 70m grid; shaded blue area- 350m grid).

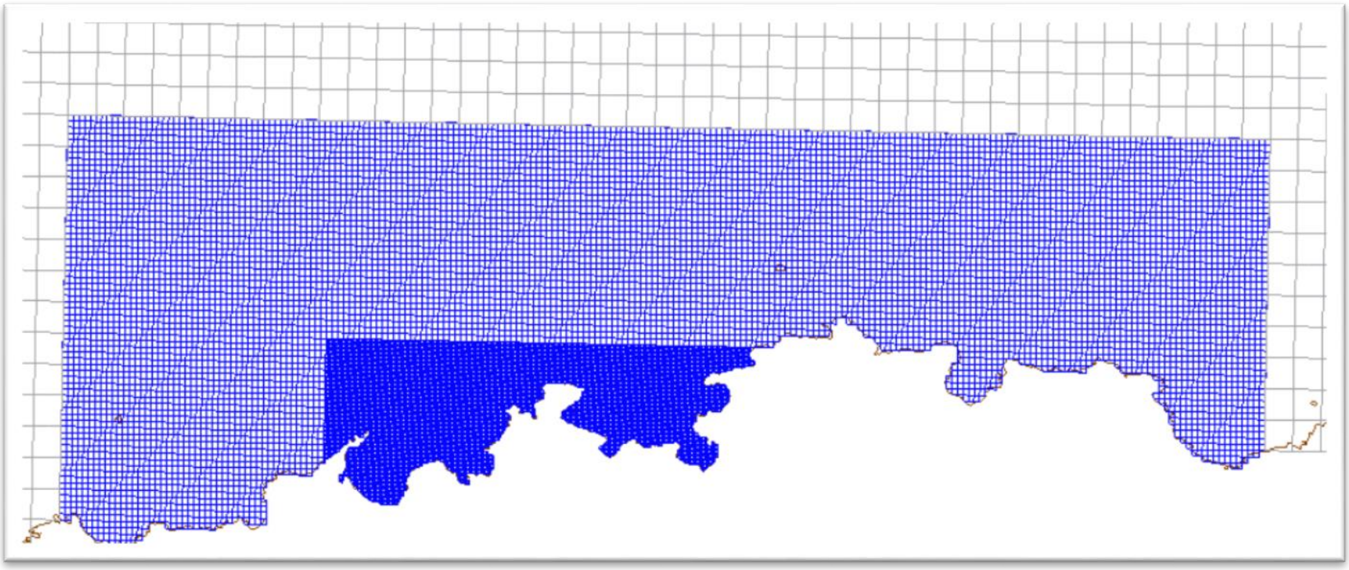


Figure 2 – HNP Wylfa Coastal Model, zoomed in view of model grids (shaded dark blue area- 23m grid; shaded light blue area- 70m grid).

Bathymetry for the model was obtained from existing UK Hydrographic Office survey data and from bespoke multibeam surveys of the area around the proposed power station. The local multibeam survey dataset is shown in Figure 3 and the final model bathymetry is shown in Figure 4.

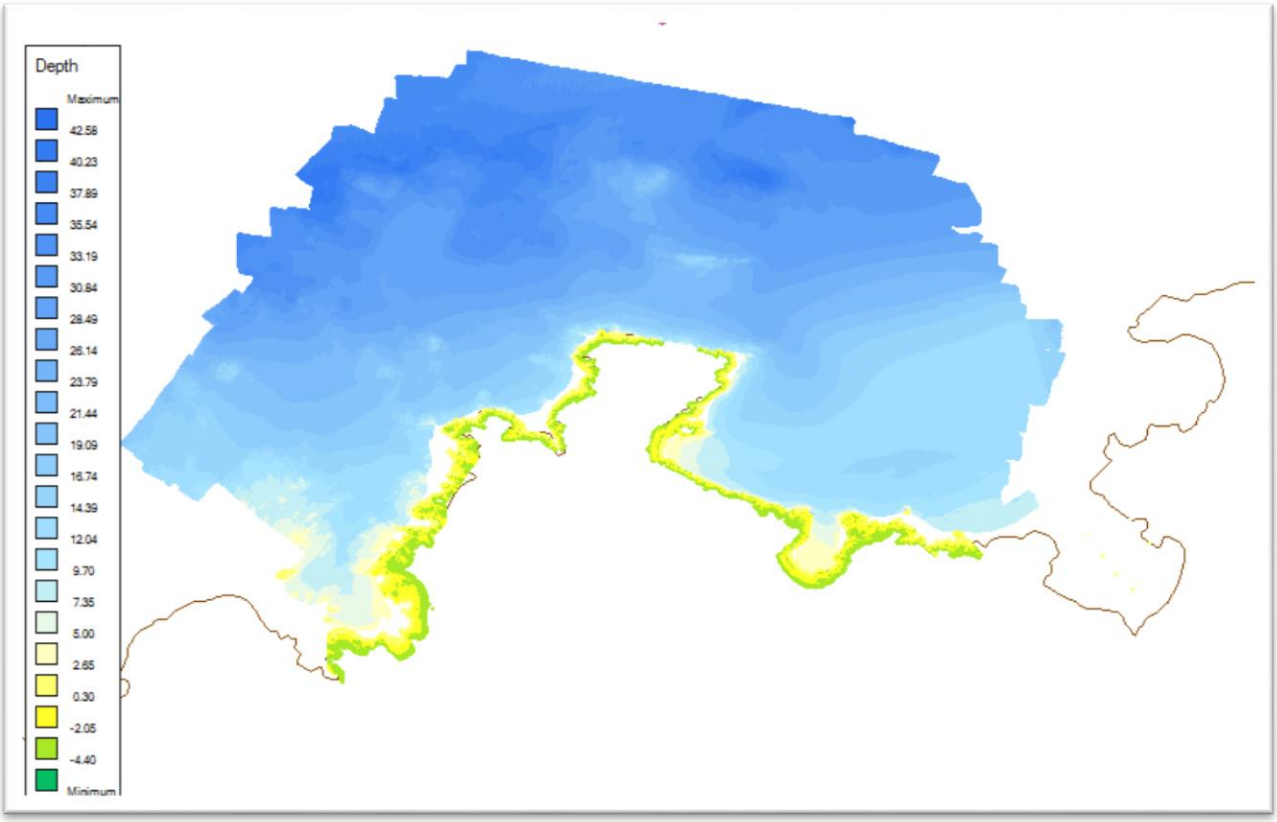


Figure 3 – HNP's Bespoke multibeam bathymetry data

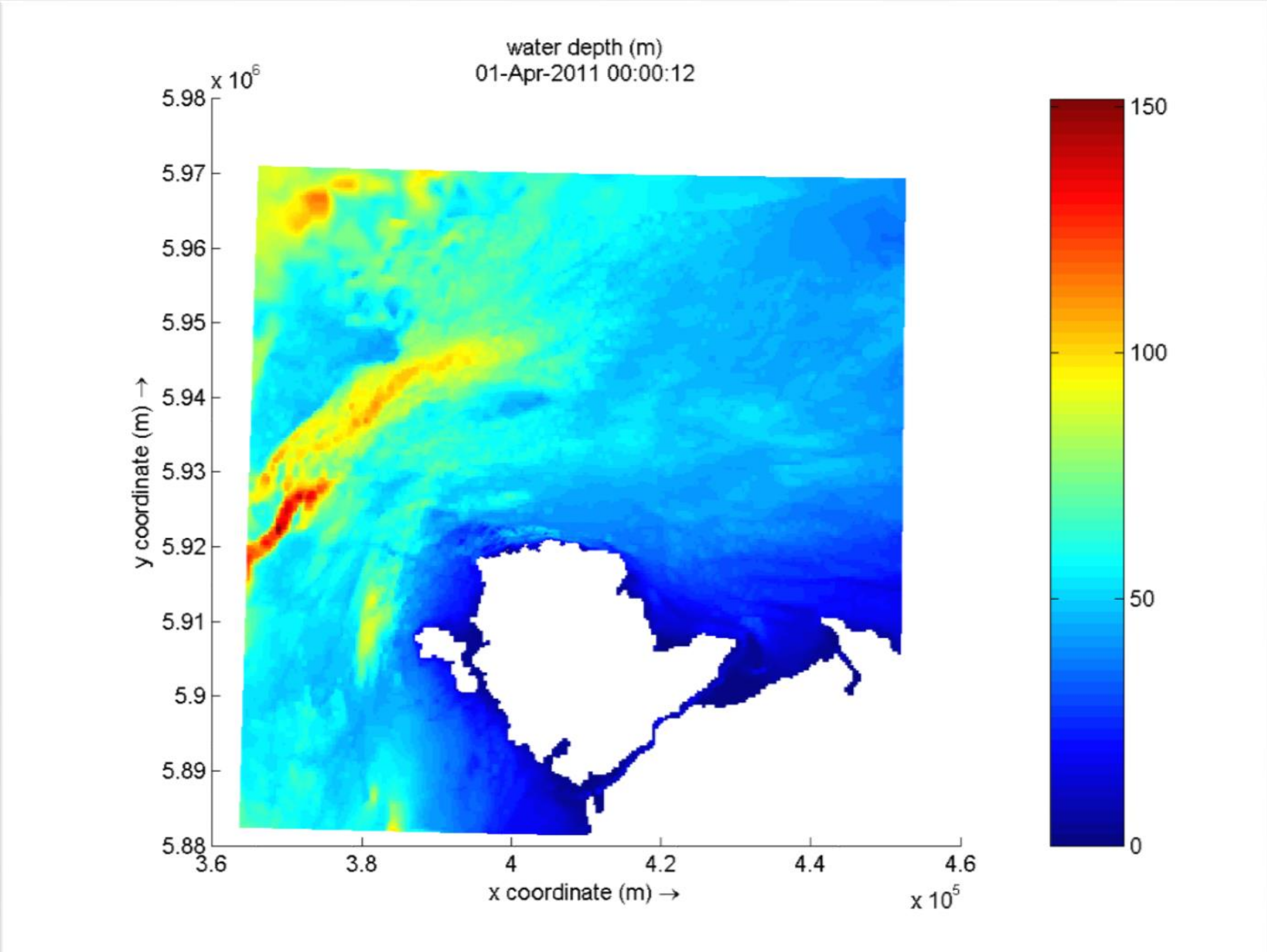


Figure 4 – Final model bathymetry

An extensive model calibration process was undertaken against a wide range of survey data, including bespoke water level and current measurements around the Wylfa Head and offshore areas. The model calibrated strongly against the available water level data, and against synoptic velocity data where a complex set of gyres either side of Wylfa Head are correctly reproduced by the model. An example of this synoptic comparison is shown in Figure 5.

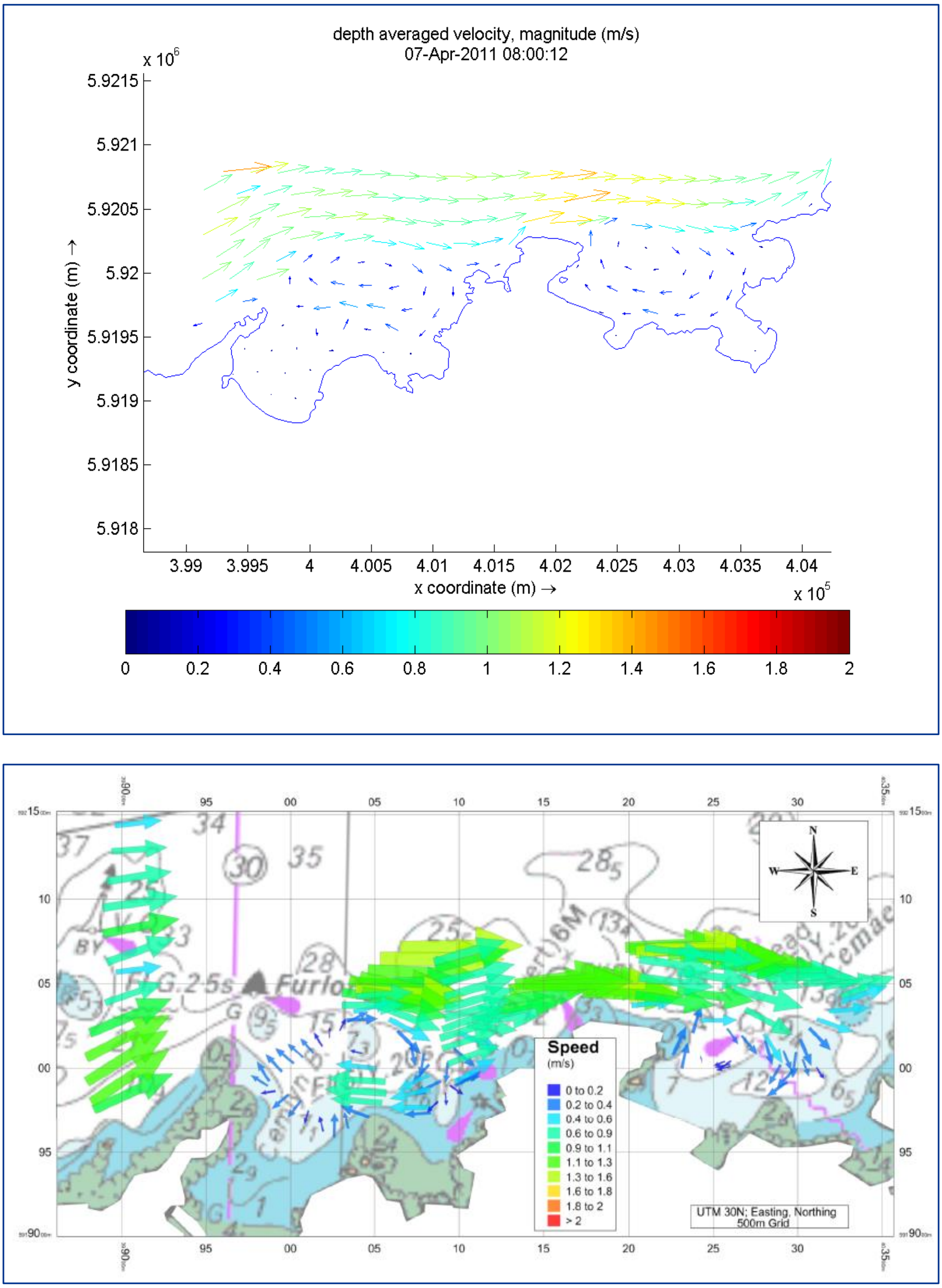


Figure 5 – Example of synoptic comparison, model (top) and survey data (bottom)

A series of dye releases was undertaken to verify the model hydrodynamics and to allow for calibration of the model dispersion parameters. The robust model performance when compared with the dye data gives confidence in the model skill in terms of both hydrodynamics and dispersion.

Finally, the model was calibrated against aerial thermal imagery of the (then) existing Wylfa thermal plume discharge, thus ensuring robust model performance for advection and dispersion as well as heat exchange processes.

The model build, calibration and validation process was described in detail in (*HNP, 2016*).

2.1 Model Audit

ABP Marine Environmental Research (ABPmer) were commissioned to undertake a detailed 3rd party audit of the modelling, which they undertook in two stages (*ABPmer 2016*). The audit considered:

- The choice of model software
- The model build (extents, resolution, bathymetry, boundary data)
- The model calibration (including water levels, flow velocities, dispersion)
- The model validation (including water levels, flow velocities, dispersion)

The audit process was carried out in two stages to allow for feedback between the initial findings of the process and the team developing the model. This engagement process was found by the auditors to be extremely productive, allowing improvements to be made in the demonstration of the model performance. As a result, the model was found to be Fit for Purpose for the key purpose of investigating the thermal dispersion requirements of the marine consent.

3. Modelling of the Sewage Effluents

The Delft3D model was configured as follows:

- Western Breakwater included in model simulations.
- Model run in 3D mode as per previous work.
- Three treated sewage effluent discharges modelled, namely Breakwater North (BWN) (discharge point WS1 in the Cooling Water Discharge Environmental Permit Application), Campus and DCWW, with Campus and DCWW sharing the same outfall location. Outfall locations are shown in **Figure 6**. Flow rates are described in Table 1. As an additional sensitivity test to the location of the DCWW discharge, an alternative ("DCWW-Alt") outfall was located approximately 50m to the north of the original location.
- Escherichia coli (EC) and Intestinal enterococci (IE) indicator bacteria were both included. Concentrations and die-off are described in Table 1.
- The model simulation time-frame was 28 days, allowing 14 days to achieve dynamic equilibrium and 14 days of a full Neap-Spring-Neap tide cycle for data output, which is considered sufficient to capture any variation within typical tidal cycle.
- No wind was included for the main application model runs, however a "worst case" onshore wind sensitivity simulation was undertaken. The onshore wind direction was northerly, agreed with NRW on the basis that effluent would be carried around Wylfa Head by the dominant tidal flows, and then "driven" into Cemaes Bay by the northerly wind. The selected wind speed (4.7m/s, or 9.14 knots) was determined / agreed during the Cooling Water modelling as being the mean speed for wind from the northerly sector as recorded at RAF Valley during the period 2003 to 2012.

Figure 6 – Modelled Outfall Locations

Table 1 – Modelled Effluent Parameters

Discharge	Release location	Flow rate l/s	E.coli count per 100ml	E.coli T90 value (constant)	I. enterococci count per 100ml	I. enterococci T90 (constant)
HNP- Main Site **"BWN"**	Tip of northern breakwater 234475 394323	18.5*#	100,000	40 hours	40,000	80 hours
HNP- Site Campus **"Campus"**	Wylfa head, western side 235237 394373	18.5*#	100,000	40 hours	40,000	80 hours
DCWW Wylfa Head- onshore **"DCWW"**	Wylfa head, western side 235237 394373	18*	100,000	40 hours	40,000	80 hours
DCWW Wylfa Head- alternative **"DCWW-Alt"**	Wylfa head, western side 235240 394417	18*	100,000	40 hours	40,000	80 hours

*** All modelled flow rates are continuous Full Flow to Treatment (FFT). FFT is the design maximum flow which may be carried through the treatment process and is significantly higher than the usual Dry Weather Flow (DWF) treated at the works. FFT has been considered in this study as a reflection of the highly conservative approach adopted throughout.**

 # 18.5/s was selected as a worst case continuous flow value and exceeds the proposed discharged volumes when factored to a continuous flow rate.

3.1 Determination of Effluent Parameters

Robust model predictions regarding bacteria concentrations at the Cemaes bathing water are dependent on a number of factors, as follows:

1. Sound representation of hydrodynamic flows. Calibrated and validated extensively as described above.
2. Sound representation of effluent dispersion. Calibrated and validated extensively as described above.
3. Correct definition of effluent parameters, namely flow rate (well defined), bacterial count and bacterial mortality.

The effluent parameters presented in Table 1 have been derived following extensive discussions between HNP, DCWW and NRW.

3.1.1 Bacterial Count

The values used are appropriate to secondary treated effluent. The values presented have been suggested by DCWW, and are based on conservative assessment of geomean values from extensive UK water industry experience underpinned by a wide range of sampling exercises described, for example, in (*Kay et al 2007*).

DCWW have used similar values for modelling of other coastal secondary treated effluent discharge sites, which NRW have subsequently reviewed.

3.1.2 Bacterial Mortality

Bacterial mortality rates are defined in terms of T_{90}, i.e. the time taken (in hours) for the bacterial population to decrease by 90%.

The values applied in the current study have been developed over a number of DCWW modelling projects and were derived from the validation of models used in their recent Coastal Investigations programme. The values were agreed by NRW as part of the Coastal Investigations sign off for the modelling in each location / area. In particular, for studies along the north Wales coast, DCWW validated the models against bathing / shellfish water data using T_{90} as a variable. In these cases 40 hours for E.coli and 70 hours (*c.f.* 80 hours used in the present study) for I. enterococci gave the best fit for bathing season conditions.

During the study review discussions in December 2018, NRW requested sensitivity testing be carried out for reduced bacterial mortality rates, in line with the generally conservative approach adopted throughout. T_{90} values for this simulation were therefore doubled to 80 hours and 160 hours for E.coli and I. enterococci respectively. It should be noted that these values are not supported by water industry experience or the scientific literature, they are simply a very conservative sensitivity test. The result of this test are nonetheless of interest to the study.

4. Modelling Results

Results of the model applications and sensitivity studies are described below. Model outputs are presented in terms of timeseries of bacteria concentrations as predicted to occur at the Cemaes bathing water monitoring point. The actual values measured by physical sampling at this location would also include contributions from intermittent DCWW assets (storm discharges) and, significantly, diffuse inputs from the catchment, principally agriculture run-off. These inputs are not the subject of this study, which is intended purely to consider the continuous discharges identified above.

For context, Table 2 gives the regulatory standards under the revised Bathing Water Directive (*rBWD 2006*), by which bathing water quality is categorised.

Table 2 – Bathing Water Standards as defined in the revised Bathing Water Directive and Annexes.

For coastal waters and transitional waters

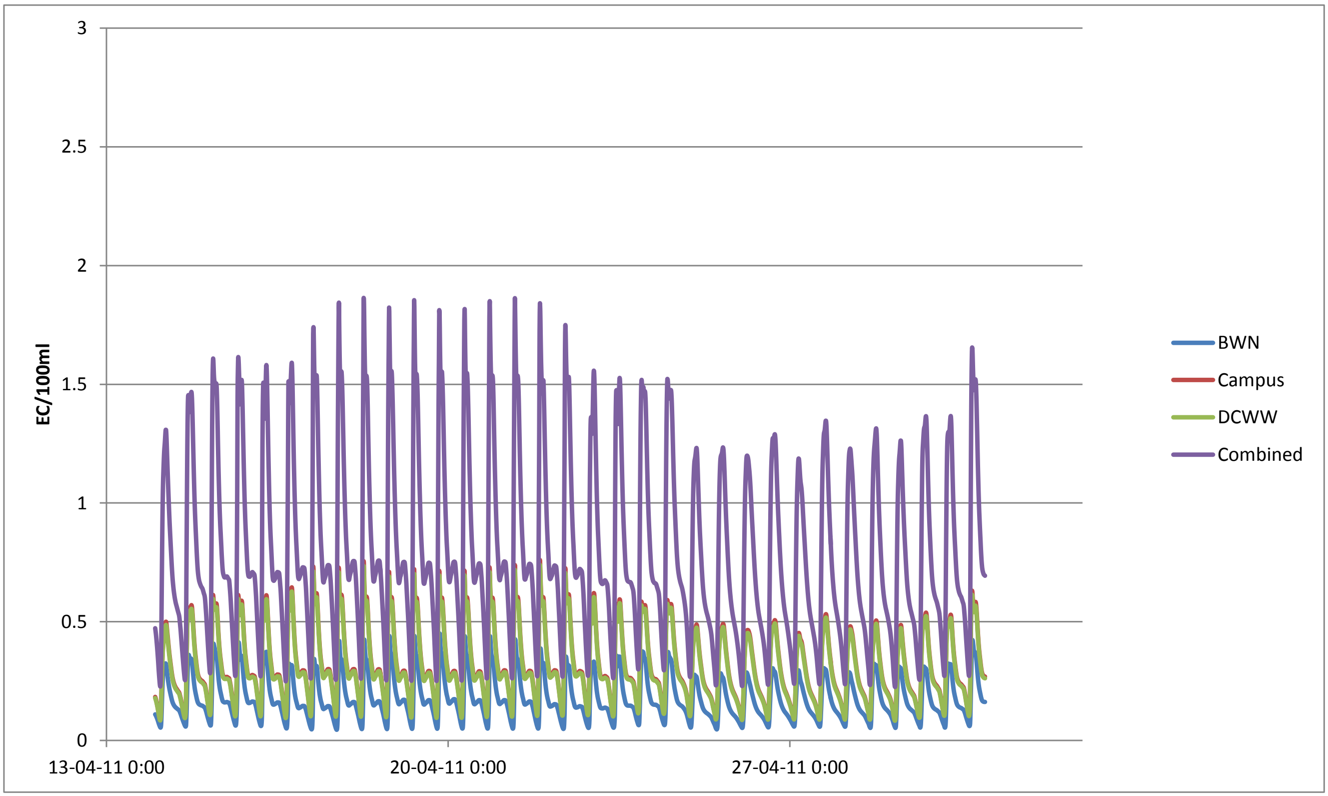
	A	B	C	D	E
	Parameter	**Excellent quality**	**Good quality**	**Sufficient**	**Reference methods of analysis**
1	Intestinal enterococci (cfu/100 ml)	100 (3)	200 (3)	185 (4)	ISO 7899-1 or ISO 7899-2
2	Escherichia coli (cfu/100 ml)	250 (3)	500 (3)	500 (4)	ISO 9308-3 or ISO 9308-1

(1) Based upon a 95-percentile evaluation. See Annex II.
(2) Based upon a 90-percentile evaluation. See Annex II.
(3) Based upon a 95-percentile evaluation. See Annex II.
(4) Based upon a 90-percentile evaluation. See Annex II.

4.1 E.coli

Timeseries of predicted E.coli concentrations at Cemaes bathing water are shown in Figure 7. Note the y-axis scale, adjusted so that the timeseries profile can be seen clearly. It would be more usual to scale the y-axis in terms of the relevant water quality standards, and this has been done in Figure 8 in terms of the Excellent water quality standard for E.coli (250 CFU / 100ml). The resultant plot provides useful context.

Timeseries presented include the “combined” results, calculated by summing the BWN, Campus and DCWW outputs.



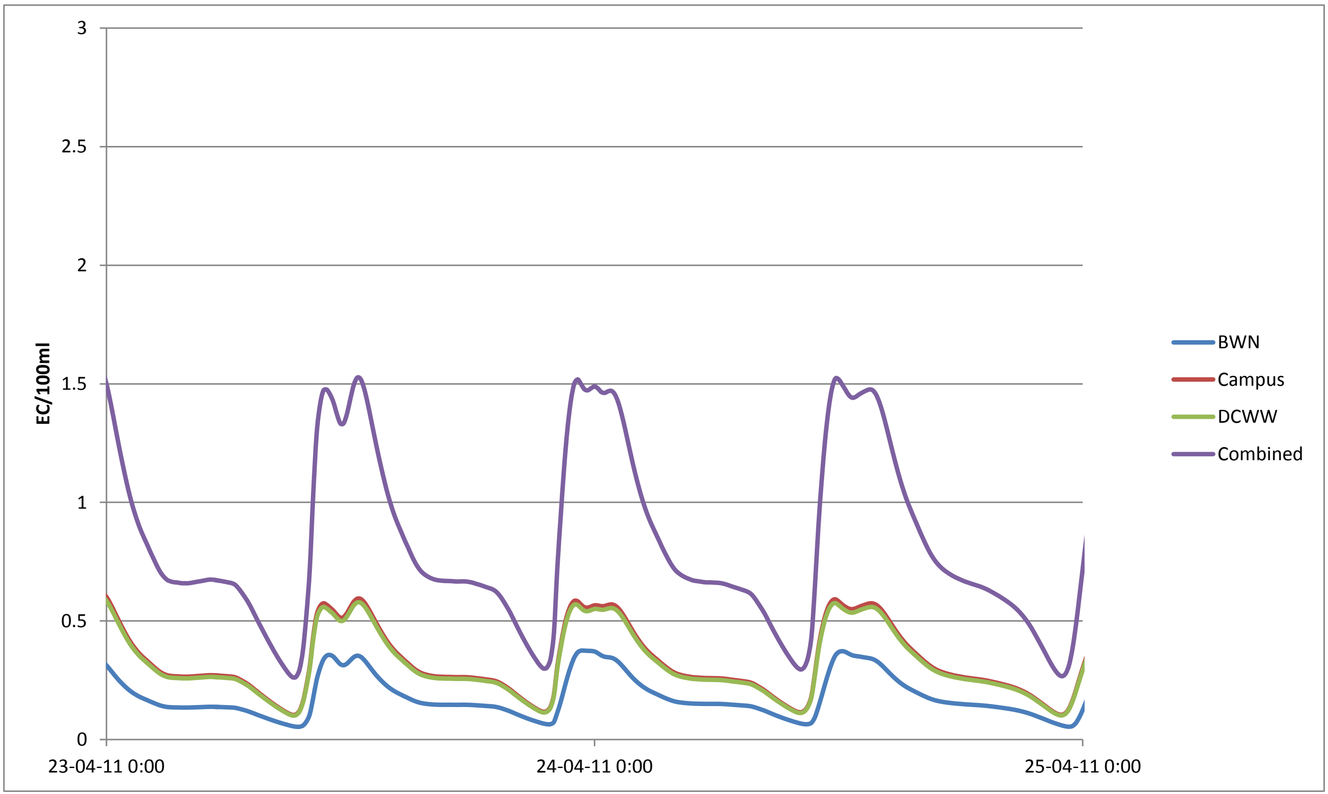


Figure 7 – E.coli at Cemaes bathing water, full output period (top), intermediate tides (bottom).

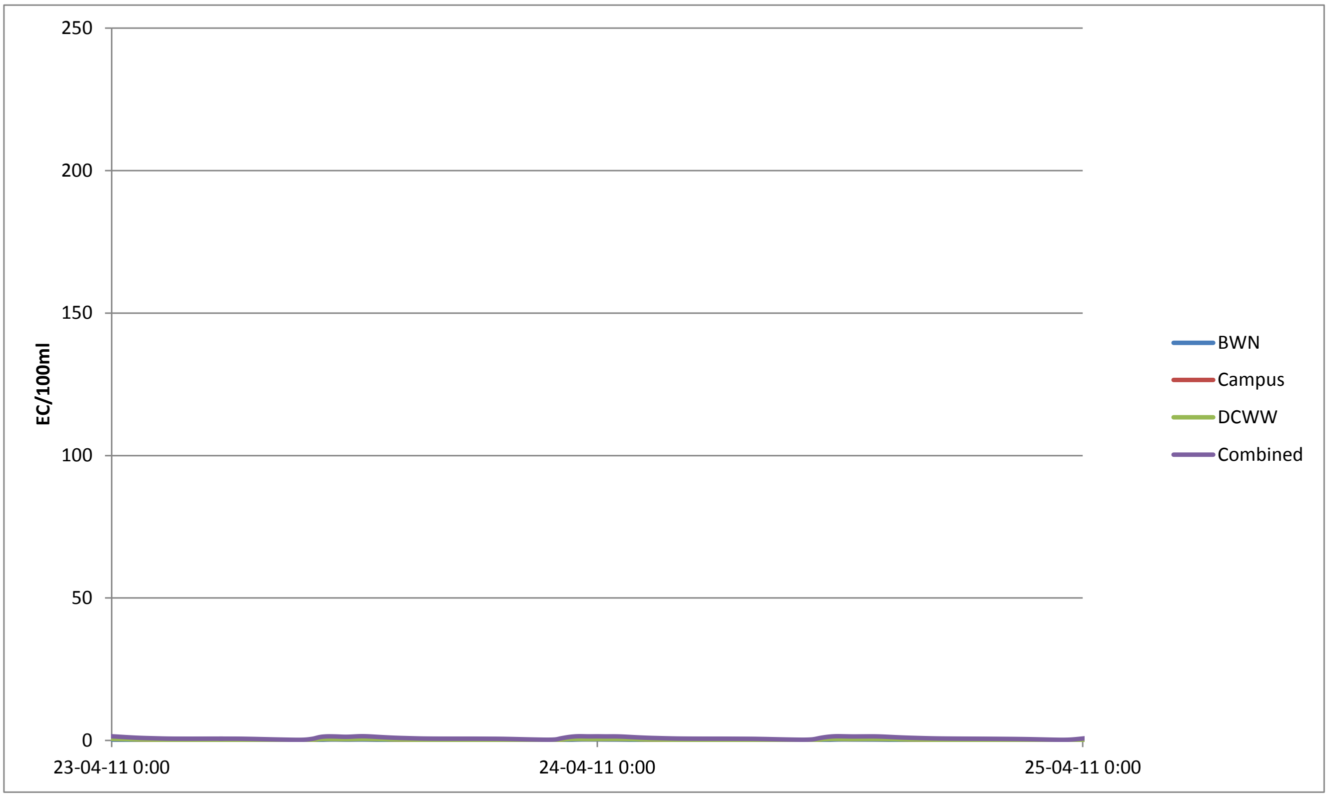


Figure 8 – E.coli at Cemaes bathing water, y-axis scaled according to the rBWD Excellent water quality standard.

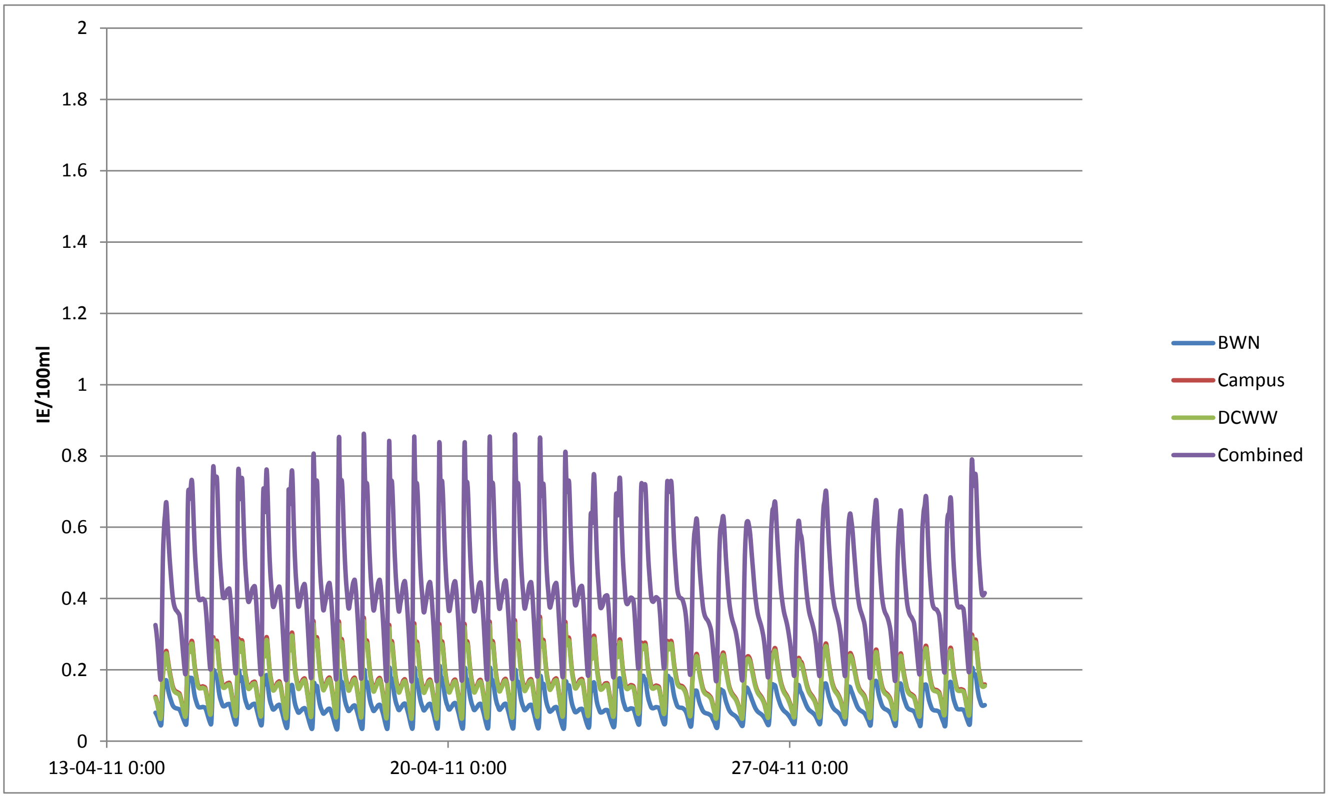
Predicted 95th percentile E.coli concentrations at Cemaes bathing water are as follows:

- BWN discharge – 0.35 CFU / 100ml
- Campus discharge – 0.60 CFU / 100ml
- DCWW discharge – 0.58 CFU / 100 ml
- Combined discharges – 1.53 CFU / 100ml

All of these values, timeseries and statistics, are very low in the context of the rBWD 95%ile standards (Excellent - 250 CFU / 100 ml; Good – 500 CFU / 100 ml).

4.2 Intestinal enterococci

Timeseries of predicted IE concentrations at Cemaes bathing water are shown in Figure 9. Timeseries presented include the “combined” results, calculated by summing the BWN, Campus and DCWW outputs.



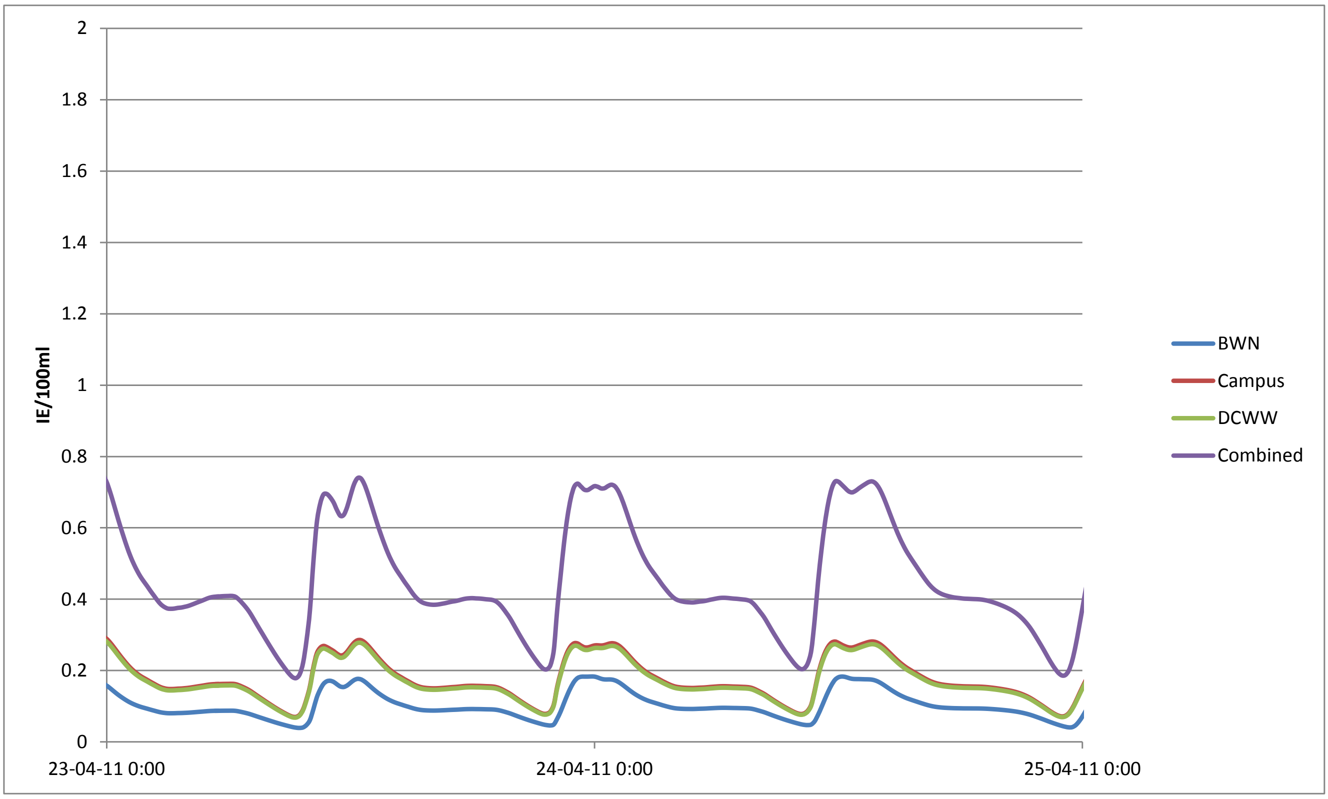


Figure 9 – IE at Cemaes bathing water, full output period (top), intermediate tides (bottom).

Predicted 95th percentile IE concentrations at Cemaes bathing water are as follows:

- BWN discharge – 0.17 CFU / 100ml
- Campus discharge – 0.28 CFU / 100ml
- DCWW discharge – 0.27 CFU / 100 ml
- Combined discharges – 0.72 CFU / 100ml

All of these values, timeseries and statistics, are very low in the context of the rBWD 95%ile standards (Excellent - 100 CFU / 100 ml; Good – 200 CFU / 100 ml).

5. Model Sensitivity Testing

A range of sensitivity tests, as described above, were agreed with NRW, in order to maximise confidence in, and understanding of, the model predictions. The results of the sensitivity testing are presented below.

5.1 Sensitivity Testing – Bacterial Mortality (T_{90} values)

Sensitivity testing for T_{90} values, where T_{90} values were doubled to 80 hours and 160 hours for E.coli and IE, was undertaken in order to test the sensitivity of the model predictions to a very large change in the bacteria die-off rate. Results are shown in Figure 10 for E.coli and Figure 11 for IE.

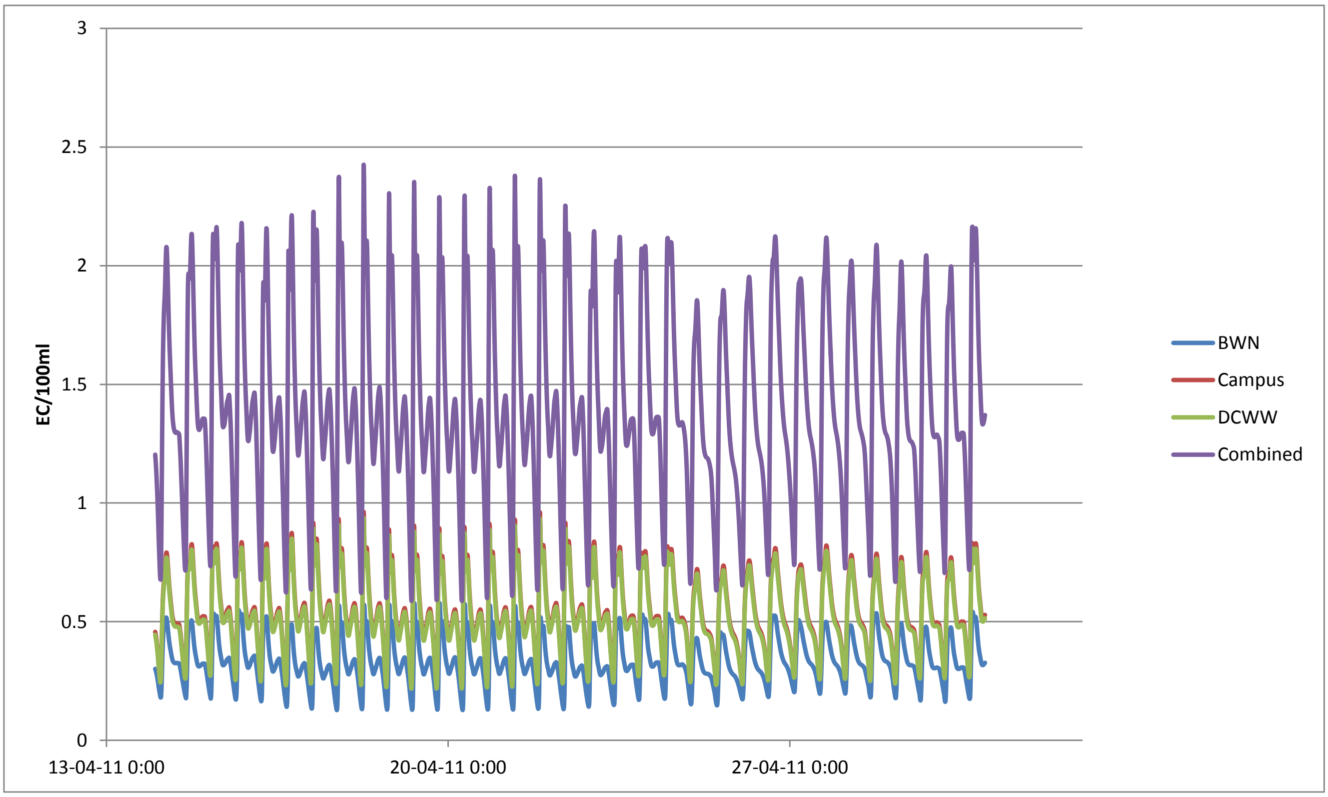


Figure 10 – E.coli at Cemaes bathing water, T_{90} sensitivity

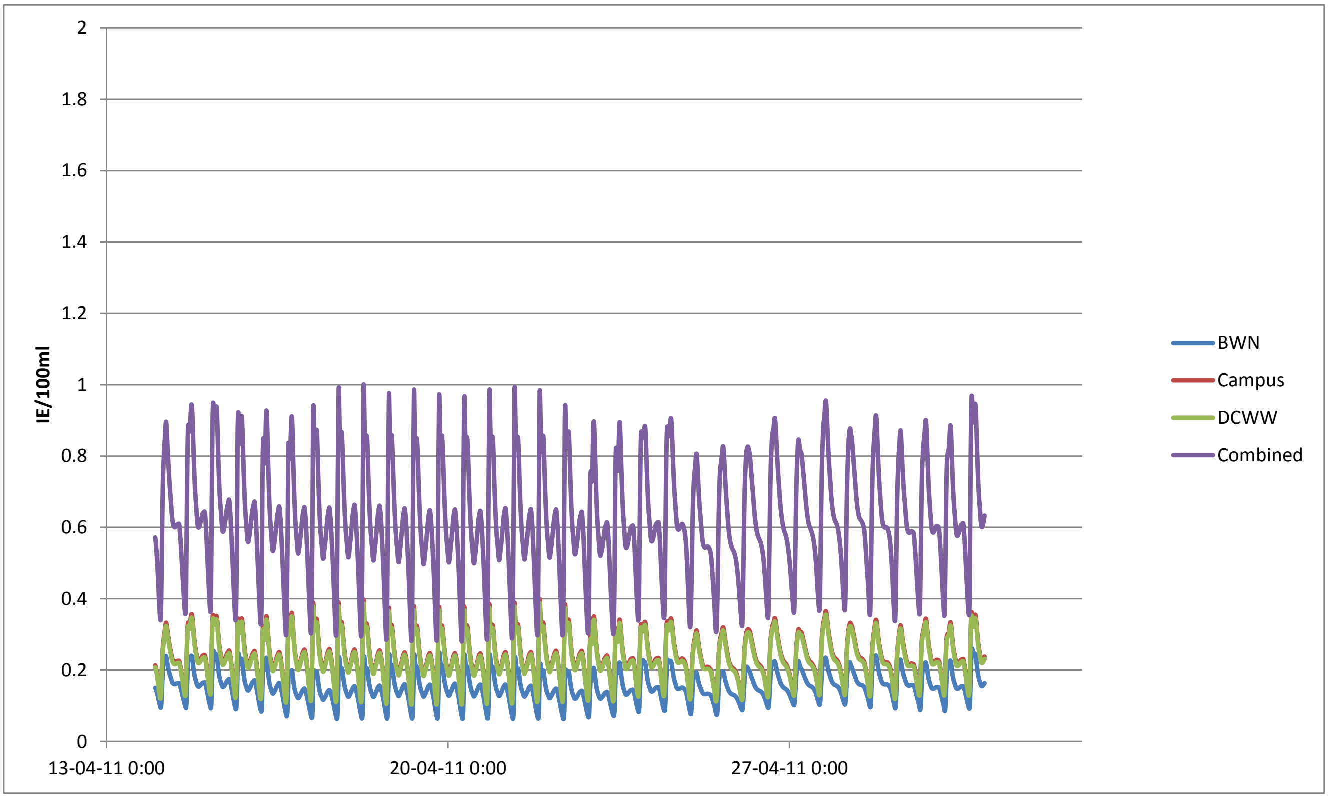


Figure 11 – IE at Cemaes bathing water, T_{90} sensitivity

Predicted 95th percentile E.coli concentrations at Cemaes bathing water are as follows (original values in parentheses):

- BWN discharge – 0.51 (0.35) CFU / 100ml
- Campus discharge – 0.80 (0.60) CFU / 100ml
- DCWW discharge – 0.78 (0.58) CFU / 100 ml
- Combined discharges – 2.08 (1.53) CFU / 100ml

Predicted 95th percentile IE concentrations at Cemaes bathing water are as follows (original values in parentheses):

- BWN discharge – 0.23 (0.17) CFU / 100ml
- Campus discharge – 0.34 (0.28) CFU / 100ml
- DCWW discharge – 0.33 (0.27) CFU / 100 ml
- Combined discharges – 0.88 (0.72) CFU / 100ml

From the timeseries plots and statistical values, it can be seen that the increases in bacterial concentrations associated with doubling the T_{90} times are very small (<<1 CFU / 100ml in all instances) and not significant in terms of compliance with rBWD standards.

5.2 Sensitivity Testing – Northerly Wind

Sensitivity testing for worst case wind conditions, whereby a continuous onshore northerly wind was applied to the model simulations, was undertaken. In keeping with the conservative approach adopted throughout, this simulation did not include the effect of wind generated waves, which would tend to reduce bacterial concentrations through increased dispersion and turbulent mixing. The results are presented in Figure 12 for E.coli and Figure 13 for IE.

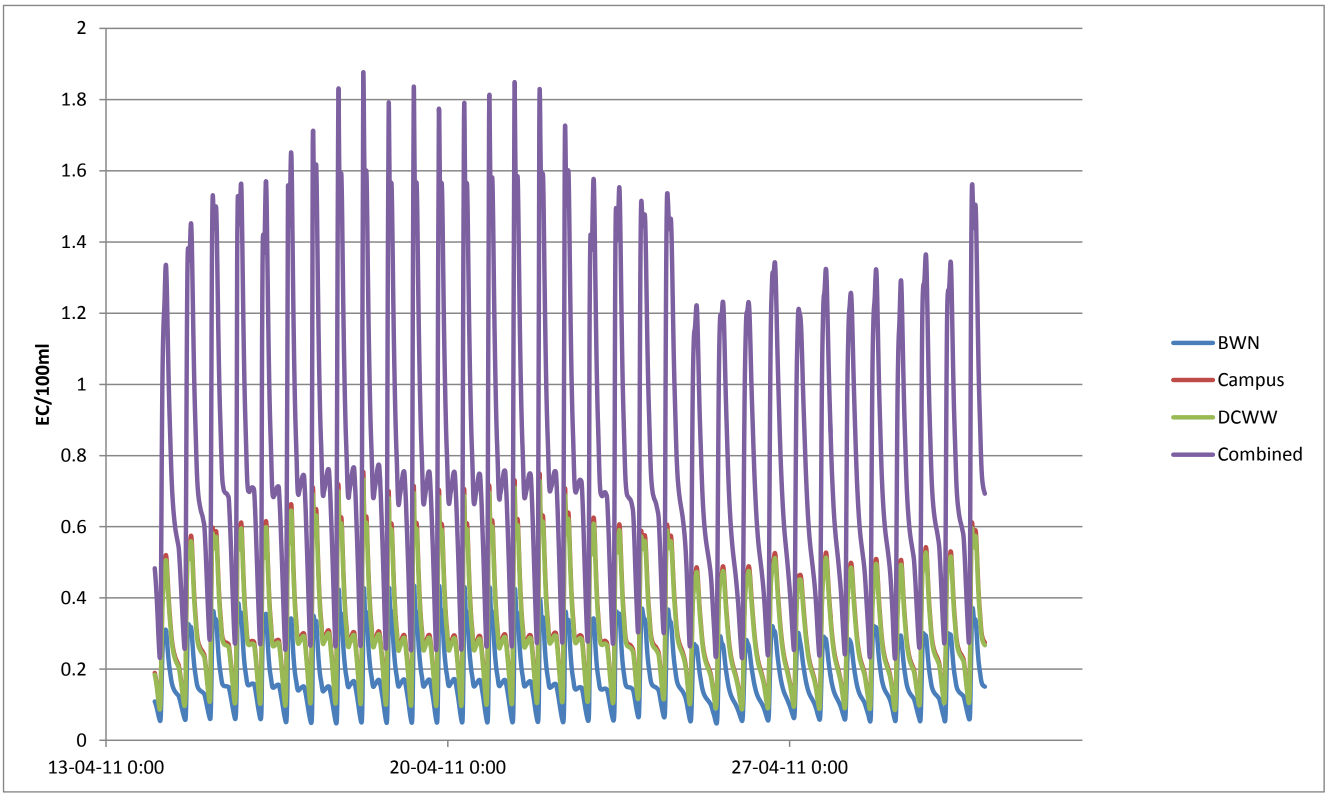


Figure 12 - E.coli at Cemaes bathing water, northerly wind sensitivity simulation

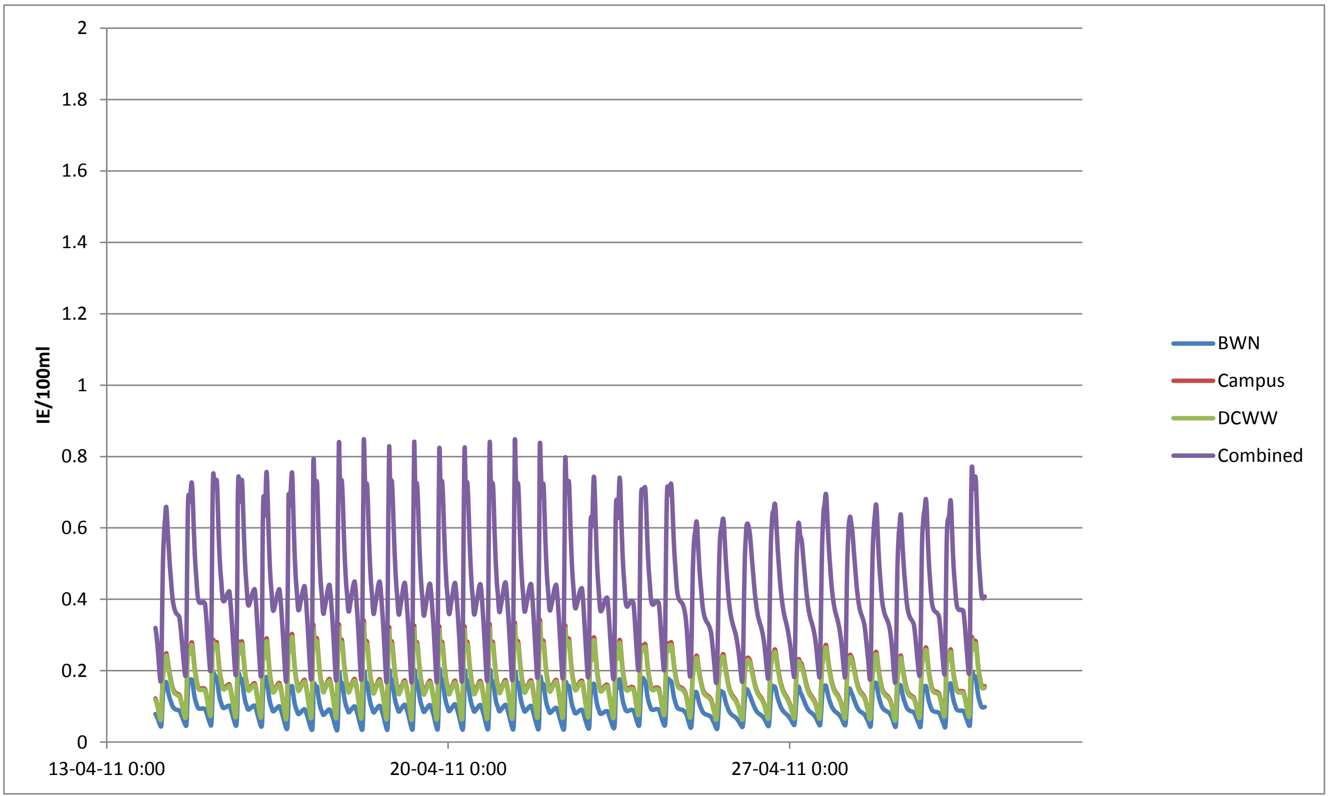


Figure 13 - IE at Cemaes bathing beach, northerly wind sensitivity simulation

Predicted 95th percentile E.coli concentrations at Cemaes bathing water are as follows (original values in parentheses):

- BWN discharge – 0.35 (0.35) CFU / 100ml
- Campus discharge – 0.61 (0.60) CFU / 100ml
- DCWW discharge – 0.59 (0.58) CFU / 100 ml
- Combined discharges – 1.54 (1.53) CFU / 100ml

Predicted 95th percentile IE concentrations at Cemaes BW are as follows (original values in parentheses):

- BWN discharge – 0.17 (0.17) CFU / 100ml
- Campus discharge – 0.28 (0.28) CFU / 100ml
- DCWW discharge – 0.27 (0.27) CFU / 100 ml
- Combined discharges – 0.72 (0.72) CFU / 100ml

From the above predictions, it is clear that a northerly onshore wind has a very marginal impact on bathing water quality at Cemaes, particularly when considered in the context of the rBWD standards. This result is in line with expectation, since the water movements around Wylfa Head and past / into Cemaes Bay are dominated by tidal flows.

5.3 Sensitivity Testing – Location of DCWW Discharge

Results of the sensitivity test for the alternative location of the DCWW discharge (50m to the north of the modelled "DCWW" location) are presented below in Figure 14 and Figure 15. The results are presented so as to allow direct comparison between predicted bacteria concentrations at Cemaes bathing water arising from the DCWW and the DCWW-Alt discharge locations.

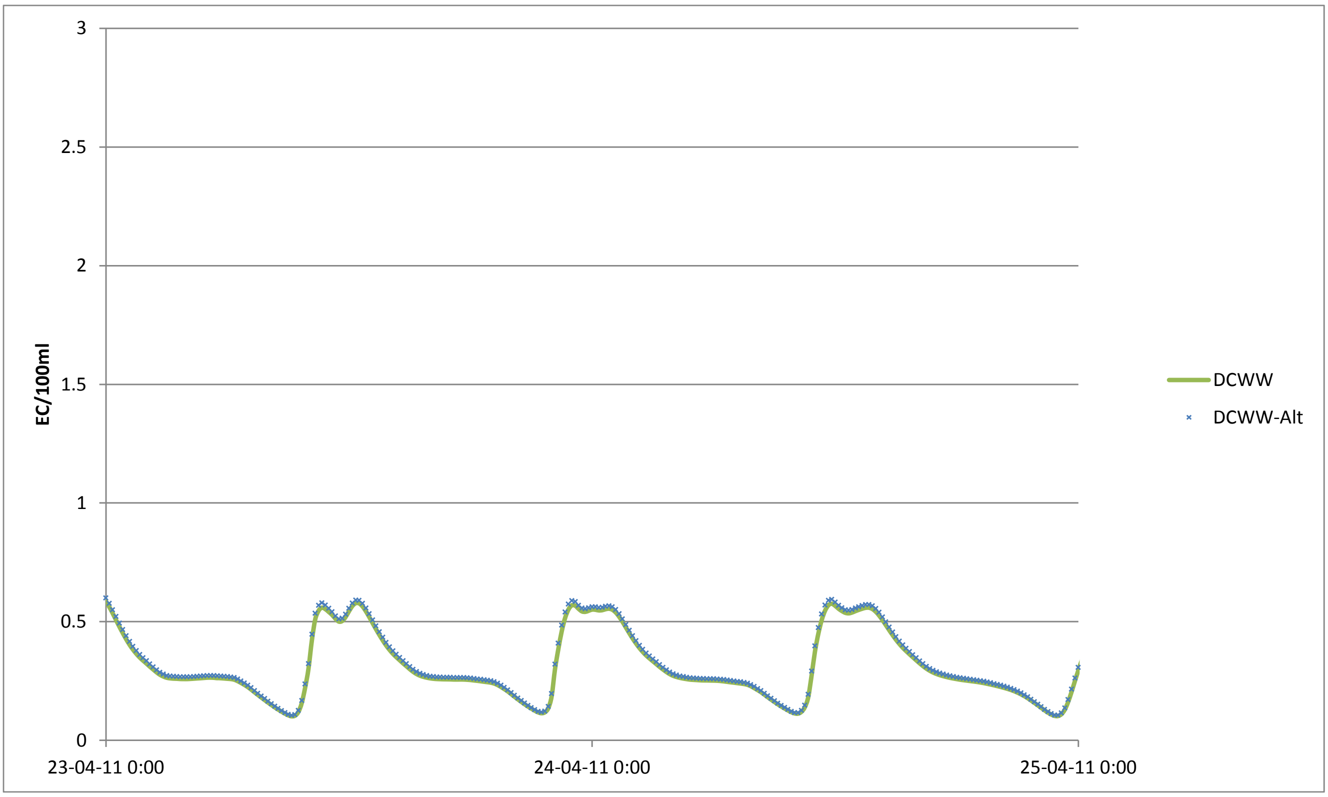


Figure 14 – E.coli predictions at Cemaes bathing water, for the DCWW and DCWW-Alt discharges locations.

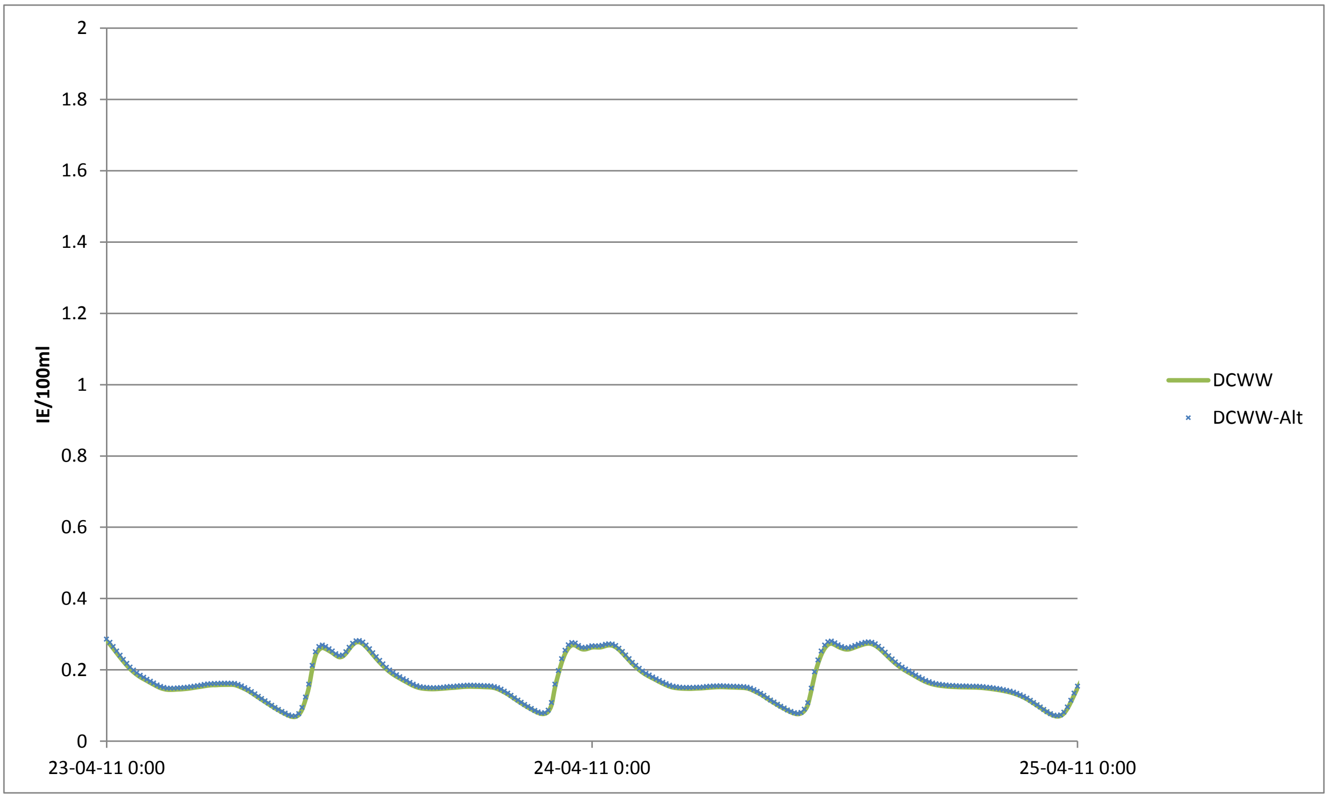


Figure 15 - IE predictions at Cemaes bathing water, for the DCWW and DCWW-Alt discharges locations.

Predicted 95th percentile E.coli concentrations at Cemaes bathing water are as follows:

- DCWW discharge – 0.58 CFU / 100 ml
- DCWW-Alt discharge – 0.60 CFU / 100 ml

Predicted 95th percentile IE concentrations at Cemaes bathing water are as follows:

- DCWW discharge – 0.27 CFU / 100 ml
- DCWW-Alt discharge – 0.28 CFU / 100 ml

From the above, it is clear that not only is the impact of the DCWW discharge on bathing water quality well below measurable limits in terms of water quality sampling, but also the effect of moving the discharge location 50 m is not significant.

6. Conclusions

The existing HNP Wylfa advection dispersion model has been applied to consider the impact of sewage effluents from Breakwater North, Campus and DCWW discharges on bathing water quality at the designated Cemaes bathing water.

The model has previously been subject to a very extensive build, calibration and validation process, and a successful 3rd party two-stage audit process.

Model input parameters are based on industry measurements and scientific literature, with conservative assumptions being made where appropriate.

A number of sensitivity tests have also been undertaken to give further confidence to the model predictions; in each case the sensitivity test changed the model predictions to some degree – and in line with expectation - but did not result in significant changes to the model predictions in the context of rBWD standards.

The predicted impact of the Breakwater North and Campus discharges, operating together with the DCWW discharge, is seen in the context of the revised Bathing Water Directive standards.

For E.coli, the 95%ile standard for Excellent bathing water quality is 250 CFU / 100ml. The combined effect of all three discharges operating at Full Flow to Treatment is predicted to be 1.53 CFU / 100 ml.

For IE, the 95%ile standard for Excellent bathing water quality is 100 CFU / 100ml. The combined effect of all three discharges operating at Full Flow to Treatment is predicted to be 0.72 CFU / 100ml.

For both E.coli and IE, the concentrations predicted by the model, even in combination, are well below measurable limits in terms of water quality sampling.

References

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(Kay et al 2007) - Kay, D., et al., Faecal indicator organism concentrations in sewage and treated effluents; Water Res. (2007), doi:10.1016/j.watres.2007.07.036

rBWD (2006) - *Directive 2006/7/EC of the European Parliament and of the Council of 15 February 2006 concerning the management of bathing water quality and repealing Directive 76/160/EEC*